METHANE de-NOX® for Utility PC Boilers

Quarterly Technical Progress Report
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DISCLAIMER

ABSTRACT

Large-scale combustion tests with caking bituminous coal has stopped. This stoppage has come about due to limitations in current funding available to continue large scale research and development activities at Riley's Commercial Burner Test Facility (CBTF) of the PC Preheat technology. The CBTF was secured and decommissioned in the previous quarter; work this quarter has focused on disposition of PC Preheat experimental equipment at the CBTF as well as methods for disposal of about 100 tons of residual PRB test coal in storage. GTI was granted a no-cost time extension through September 2005; a final report is due in December 2005.

TABLE OF CONTENTS

Disclaimer 2
Abstract 3
Table of Contents 4
Executive Summary 5
Experimental 6
Results and Discussion 8
Conclusions 9
References 9
Milestone Status Table 10

EXECUTIVE SUMMARY

Project Objectives: The overall project objective is the development and validation of an innovative combustion system, based on a novel coal preheating concept prior to combustion, that can reduce NO_x emissions to 0.15 lb/million Btu or less on utility pulverized coal (PC) boilers. This NO_x reduction should be achieved without loss of boiler efficiency or operating stability, and at more than 25% lower levelized cost than state-of-the-art SCR technology. A further objective is to ready technology for full-scale commercial deployment to meet the market demand for NO_x reduction technologies resulting from the EPA's NO_x SIP call.

Background: A novel pulverized coal-preheating approach for NO_x reduction was developed by the All Russian Thermal Engineering Institute (VTI) for use on PC utility boilers. The approach consists of a burner modification that preheats pulverized coal to elevated temperatures (up to 1500°F) prior to coal combustion. This releases coal volatiles, including fuel-bound nitrogen compounds, into a reducing environment, which converts the coal-derived nitrogen compounds to molecular N_2. The quantity of natural gas fuel required for PC preheating is in the range of 3 to 5% of the total burner heat input. Basic combustion research and development of the preheat PC burner was conducted by VTI in the early 1980's. Following these promising laboratory results, commercial-scale PC preheating burners of 30 and 60 MW_t capacity were developed and demonstrated in field tests conducted in several Russian power stations.

The advanced PC preheating combustion system being developed in this project for direct-fired PC boilers combines the modified VTI preheat burner approach with elements of IGT's successful METHANE de-NOX technology for NO_x reduction in stoker boilers. The new PC preheating system combines several NO_x reduction strategies into an integrated system, including a novel PC burner design using natural gas-fired coal preheating, and internal and external combustion staging in the primary and secondary combustion zones.

Design, installation, shakedown and initial PRB coal testing of a 3-million Btu/h pilot system at RPI's Pilot-Scale Combustion Facility (PSCF) in Worcester, MA demonstrated that the PC Preheat process has a significant effect on final NO_x formation in the coal burner. Modifications to both the pilot system gas-fired combustor and the PC burner led to NO_x reduction with PRB coal to levels below 100 ppmv with CO in the range of 35-112 ppmv without any furnace air staging. Pilot testing with PRB coal is complete.

Initial results of pilot testing with caking exhibited deposition and plugging of caked material inside of the gas combustor. A series of modifications to the combustor configuration and operation have been developed and tested during previous quarters, and testing of several more versions was continued in the current quarter. One of these approaches using a stainless steel liner indirectly cooled with air was successful in sustaining operation with caking coal up to 150 lb/h.

Installation and shakedown testing with natural gas and PRB coal was completed for the large-scale prototype coal preheater. Large-scale testing with PRB coal was discontinued due to the inability of the coal mill to meet the 85 MMBtu/h design firing rate. The project was therefore redirected toward design, installation and testing of the 85-million Btu/h preheater for bituminous coal. Based on extensive pilot-scale testing completed earlier in the project, 2-D modeling and design activities were then completed based on the use of staged, annular protective air films to control temperature and prevent deposition on the preheater walls.

Riley burner design engineers with guidance from GTI completed a preliminary mechanical design for a bituminous coal preheater. The design basis was developed from CFD studies conducted by GTI; materials of construction and thermal growth considerations were finalized by Riley engineers. The bituminous preheat burner consists of a multi-barrel burner coal pipe; each barrel larger in diameter then the next which facilitates implementation of an air layer on the inside surface of each barrel wall. The air layer is critical in preventing the formation and buildup of coal agglomeration on the burner coal pipe interior.

With the burner design complete, preparations for retrofitting Riley's CBTF would have normally begun. Funding limitations has stopped further research preparations, however. Attempts to secure additional funds this quarter have been unsuccessful and subsequent project work was initiated in closing down the PC Preheat technology research effort. A draft final report is planned for October 2005 and the final report is due in December.

EXPERIMENTAL

Pilot Unit

Fabrication, installation and initial testing of the pilot-scale coal preheating system were completed in the fall of 2001. The unit is sized for operation with natural gas and pulverized coal at a total firing rate of approximately 3-million Btu/h and includes all equipment and controls necessary to operate and monitor energy and environmental performance of the system. A gravimetric feeder is used to regulate pulverized coal flow through a rotary airlock into a natural gas-fired preheater combustor. The combustor produces hot combustion gases, which combine with the pulverized coal to produce a mixture of coal char and pyrolysis products at the desired test temperature.

In the original pilot system configuration, the combustor centerline was vertical and two pipe sections after the combustor provided additional residence time for the coal at the preheated conditions prior to entering the PC burner. However, pilot testing experience together with commercial design guidance from RPI redirected the development of both the pilot and commercial units toward a horizontal combustor design with no diameter change between the combustor and burner. The preheater combustor was therefore relocated to a horizontal configuration with the combustor exit coupled directly to the PC burner inlet, eliminating the two pipe sections.

In the modified pilot unit, the velocity of the devolatilization products in the combustor and burner is increased over previous pilot testing to minimize separation and impingement of coal on inner surfaces prior to reaching the burner face. The higher velocities are more consistent with standard design criteria developed by RPI for their commercial CCV burners. The higher combustor velocities were achieved by inserting a liner in the combustor to reduce its internal diameter. The liner also facilitates testing of various designs and operating approaches to eliminate plugging of the combustor with caking coals. Various liner materials, including metal and ceramic, and liner cooling methods are being developed and tested to determine their effect on wall deposition and plugging.

During testing, real time operating data are collected at 1-second intervals and recorded by the personal computer-based data acquisition system (DAS). The concentrations of CO, CO_2, O_2,

THC and NO/NO_x in the pilot unit exhaust and the furnace exit are continuously monitored by on-line gas analyzers, including a Rosemount Analytical Model 880A infrared CO analyzer, a Rosemount Analytical Model 880A infrared CO_2 analyzer, a Rosemount Model 400 flame ionization total hydrocarbons (THC) analyzer, a Rosemount Analytical Model 755R paramagnetic O_2 analyzer, and a ThermoElectron Model 14A chemiluminescence NO_x analyzer.

The preheater gas combustor temperatures are monitored by thermocouples installed on both the outer walls and inside of the combustion chamber. Temperature of the gas/air mixture is monitored in the gas/air plenum entering the combustor nozzles.

Large-Scale Prototype Unit

The CBTF comprises a large horizontally fired dry bottom furnace capable of testing full-scale burner systems with firing capacities up to 100 MMBtu/h. The furnace is fully integrated with coal storage, grinding and feeding, emissions control, and continuous flue gas sampling and analytical subsystems.

Coal is pulverized and dried in a DB Riley Model 350 Atrita pulverizer, which is fed from a 40-ton bunker by a weigh-belt feeder and rotary valve. The mill's air supply system includes a Venturi air flow meter, fan and natural gas direct-fired heater to supply a measured amount of hot air to the pulverizer to dry and transport the coal. The CBTF is capable of firing in both the direct fire mode and from an intermediate storage bin (indirect fire). All testing will be conducted in the direct fire mode to simulate the most common firing method in the U.S market. Drying and transport air will be separated from coal stream immediately ahead of the preheater combustor inlet. The separated air will be directed to one of the three air channels in the coal burner. Secondary air will be preheated to 600 ºF by a separate fan and heater and routed to the coal burner. Air can be routed to the burner through an integral windbox plenum or through separate external ducts. Flow to each burner air channel can be regulated independently. Ports are also available at several locations for furnace air staging.

Flue gas composition will be monitored continuously. A multiple-probe sampling grid consisting of sintered Hasteloy filters is mounted in the CBTF exit duct, just upstream of the flue gas scrubber. The in-duct filters remove the majority of particulate, and the flue gas is drawn through stainless steel tubing, ice-bath conditioners, and a final filter by individual sample pumps. A rotameter at the outlet of each pump is used to admit equal flow of clean, dry sample from each grid probe to a manifold. The proper flow of sample for each continuous analyzer is supplied from the manifold.

Continuous monitors are used to measure O_2, CO_2, CO, NO/NO_x and SO_2. In addition to the gas sampling grid, a separate water-cooled probe is used to withdraw particulate samples at the CBTF outlet for determination of carbon burnout. A high velocity thermocouple probe monitors furnace outlet temperature.

The CBTF is fully instrumented to allow continuous measurement and recording or all relevant flow, pressure and temperature readings to allow complete material and energy balances to be developed for each testing period.

RESULTS AND DISCUSSION

Project Status:

Task 1.1 Pilot-Scale Design

No work was performed on this task during the reporting period.

Task 1.2 CFD Modeling

Pilot Unit

No work was performed on this task during the reporting period.

Large-Scale Prototype Unit

No work was performed on this task during the reporting period.

Task 1.3 Pilot-Scale Equipment Fabrication and Installation

No work was performed on this task during the reporting period.

Task 1.4 Pilot-Scale Testing

No work was performed on this task during the reporting period.

Task 1.5 Pilot-Scale Data Evaluation

No work was performed on this task during the reporting period.

Task 2.1 Commercial Prototype Engineering Design

No work was performed on this task during the reporting period.

Task 2.2 Baseline Data Review

No work was performed on this task during the reporting period.

Task 2.3 Commercial Prototype Construction

No work was performed on this task during the reporting period.

Task 2.4 Commercial Prototype Testing

No work was performed on this task during the reporting period.

Task 2.5 Data Processing and Evaluation

No Work was performed on this task during the reporting period.

Task 2.6 Commercialization Plan Development

This task has been deleted from the project workscope.

Task 2.7 Design and Fabrication of Commercial Burner System

This task has been deleted from the project workscope.

Tasks 1.6 & 2.8 Management and Reporting

An evaluation of project schedule and costs showed insufficient time and funding to successfully conduct large-scale preheat combustion tests with caking bituminous coal. Efforts to secure additional funding this quarter were unsuccessful as well; consequently, a decision was made to stop all work and bring PC Preheat project experimental and development efforts to a close. This quarter GTI renewed efforts with Babcock Power in the disposition of the experimental test hardware and disposal of the PRB test coal remaining in storage at the CBTF.

Plans for Next Quarter:

Work to resolve disposition of PC Preheat Test equipment at Babcock Power's CBTF and disposal of residue PRB test coal in storage (approximately 100 tons) at the CBTF. Initiate development of a draft final report.

CONCLUSIONS

Funding limitations have forced a stoppage in PC Preheat project activities. Efforts underway are focused on the proper closing down of project activities such as disposition of test hardware and residue PRB test coal in storage near the CBTF and the completion of a final report due in December 2005.

REFERENCES

N/A

Milestone Status Table: The proposed revised completion dates for all project tasks and major milestones are shown below.

ID No.	Task / Milestone Description	Planned Completion	Actual Completion	Comments
♦	Kickoff Meeting	5/2/2000	5/2/2000	Complete
1.0	Technology Development			
1.1	Pilot-Scale Design	8/31/2000	12/31/2000	Complete
1.2	CFD Modeling-Pilot and Commercial Scale	6/30/2001		Pilot-scale modeling complete
1.3	Pilot-Scale Equipment Fabrication and Installation	11/30/2000	9/30/2001	Pilot Scale complete
1.4	Pilot-Scale Testing – Caking Coal	6/15/2004		Complete
1.5	Pilot-Scale Data Evaluation – Caking Coal	6/15/2004		Complete
1.6	Task 1 Management and Reporting	7/15/2004		
♦	Task 1 Report	8/15/2004		Hold
2.0	Technology Validation			
2.1a	Commercial Prototype Engineering Design - PRB Coal	4/15/2004	6/30/2004	Complete
2.1b	Commercial Prototype Engineering Design - Caking Coal	8/30/2004		
2.2	Baseline Data Review	4/15/2004	4/15/2004	Complete
2.3a	Commercial Prototype Construction - PRB Coal	4/15/2004	6/15/2004	Complete
2.3b	Commercial Prototype Construction - Caking Coal	9/30/2004		Suspended
2.4a	Commercial Prototype Testing - PRB Coal	6/30/2004	8/30/2004	Discontinued
2.4b	Commercial Prototype Testing - Caking Coal	11/30/2004		Suspended
2.5a	Data Processing and Evaluation - PRB Coal	7/30/2004	8/30/2004	Complete
2.5b	Data Processing and Evaluation - Caking Coal	7/31//2004		
2.6	Commercialization Plan Development	--	--	Task Eliminated
2.7	Design and Fabrication of Commercial Burner System	--	--	Task Eliminated
2.8	Task 2 Management and Reporting	9/30/2005		
♦	Final Report	9/30/2005		New Date: 12/31/2005